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WEEDY ABANDONED LANDS AND THE WEED HOSTS OF THE BEET LEAF HOPPER

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INTRODUCTION

Whenever the vegetation thoroughly established on a soil is destroyed, an equilibrium of long duration is upset. This means not only the equilibrium between plants and soil but also the balance that existed between the plant and all the life that it supported. Once upset there is no quick return to the original condition. At best there is the slow, inevitable operation of the same factors which brought about and maintained the original equilibrium. And they operate effectively toward that end in so far as there is not a recurrent opposing force, such as that exerted by man, either as a conscious effort on his part or as a by-product of his activities.

The area here to be considered is in the desert shrub region; but whether shrub land, forest land, or grassland, the first occupants of such an area after it has been denuded are short-lived plants, whose seed production is enormous, whose seeds are scattered quickly and widely and germinate quickly, and whose growth is adjustable to a wide range of conditions. They may be plants that formed an inconsiderable part of the original vegetation, or, near agricultural areas, they may be introduced weeds. With these plants multiplica-

[1] Grateful acknowledgments are made to Eubanks Carsner, Senior Pathologist, Division of Sugar Plant Investigations, for his kindly assistance and encouragement in the preparation of the manuscript; to A. S. Hitchcock, Principal Botanist, Division of Botany, for identifying the grasses; to S. F. Blake, Senior Botanist, and Ivar Tidestrom, Assistant Botanist, Division of Botany, for identifying the plants other than grasses; and to A. M. Murphy, Scientific Aide, Division of Sugar Plant Investigations, for assistance in the field work on the map.

tion is rapid, soon resulting in dense stands. If the principal constituents of these stands are also plants which in the original vegetation afforded a food supply for an insect pest, or if they are introduced weeds which may act as substitute hosts, it is obvious that there is a tremendous stimulus toward a great increase and survival in the population of that insect because of the large increase of food supply per unit area. This occurs in the case of the beet leaf hopper (*Eutettix tenellus* Baker), where the great increase in its weed hosts has furnished food for enormous numbers of leaf hoppers (*3*).[2]

Large areas of weeds are common on abandoned lands throughout the dry-farming and the irrigated sections of the West. Among the most familiar are the tracts of the tumbling mustard[3] (*Norta altissima* (L.) Britton), which, when dry, resemble at a distance immense fields of ripened wheat. In the nonirrigated farming sections and in the outlying lands of the irrigated sections it is a common occurrence to find 40-acre tracts of neglected fallow lands covered with Russian thistle (*Salsola pestifer* A. Nels.).

The following discussions of the principal weeds on lands where the original vegetations have been destroyed deal for the most part with the Snake River plains of southern Idaho. For comparison there are included discussions of the more general features of the weed areas of some of the valleys of the Southwest, namely, Escalante Valley, Utah, the western part of the Mojave Desert, and the southern part of the San Joaquin Valley of California.

It is not the purpose of this circular to present detailed data, but rather to bring together facts and observations regarding the causes, extent, composition, distribution, and development of the weedy areas, inasmuch as these are of considerable interest from the standpoint of beet leaf hopper populations and the curly-top disease.[4] The observations are based on several years' work on desert shrub vegetation and on studies of weedy abandoned lands in the Snake River plains since 1928.

SNAKE RIVER PLAINS OF SOUTHERN IDAHO

GENERAL CONSIDERATIONS

The Snake River plains of southern Idaho, which are drained by the Snake River, are composed of rolling or sloping lands with an average elevation of about 4,000 feet. The climate is characterized by a low annual rainfall[5] and dry summers, the precipitation occurring chiefly in the fall, winter, and spring. Hot, dry winds are apt to be frequent in the spring and early summer months. The soils are for the most part those developed from wind-borne material (*1*, *12*) and underlain by a basaltic bedrock. The Portneuf silt loam is the most extensive type of soil. The area of alkali lands and wet, poorly drained lands is inconsiderable. Almost the entire area was at one time covered with sagebrush (*Artemisia tridentata* Nutt.), the original vegetation of this area.[6] (Fig. 1.) Greasewood (*Sarco-*

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[2] Italic numbers in parentheses refer to Literature Cited, p. 23.

[3] Also called Jim Hill mustard. *Sisymbrium altissimum* L. is a synonym.

[4] The beet leaf hopper is the carrier of the curly-top disease, a virus disease that causes heavy losses to the sugar-beet crop and also affects other plants.

[5] The average of the normal annual precipitation for 10 stations in the more central area of the Snake River plains is 9.84 inches.

[6] The vegetation of the Snake River plains is here considered as a sagebrush climax.

batus vermiculatus (Hook.) Torr.) covered a very small portion of the area, chiefly parts of the benches in the canyons and narrow strips along streams. The area covered by salt grass (*Distichlis spicata* (L.) Greene) was even less than that covered by greasewood, while shad scale (*Atriplex confertifolia* (Torr.) S. Wats.) was insignificant, in fact, entirely lacking in a major portion of the plains. However, west of the plains proper, on the lower benches of the Snake River, there are considerable areas of shad scale.

Extensive areas of the sagebrush have been denuded, to some extent accidentally, by fires, but also intentionally in clearing for cultivation. The major part of the area cleared for cultivation is now under irrigation and producing crops, but thousands of acres have been abandoned. They are, in part, nonirrigated tracts farmed

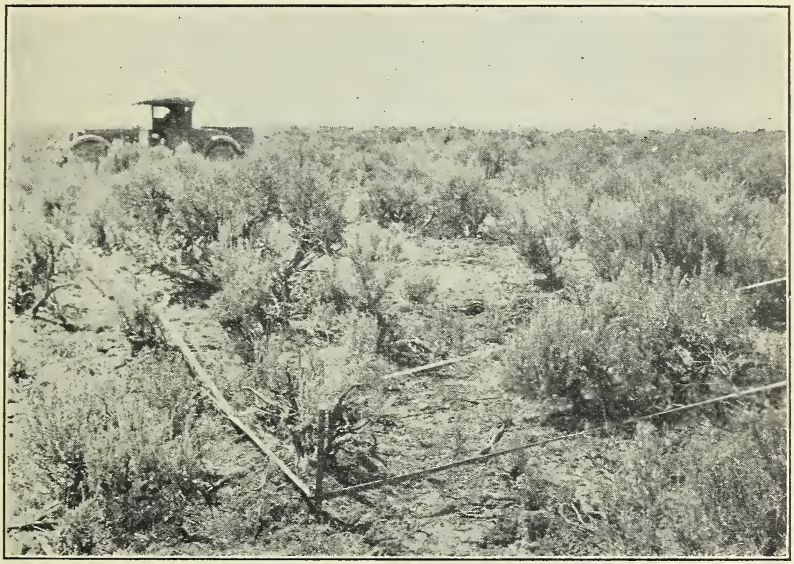

FIGURE 1.—A representative area of sagebrush, the type of vegetation that formerly covered most of the Snake River plains. The ground spaces, roughly equal to the spread of the crowns of the denser shrubs, are covered with a matting of mosses. The remaining soil spaces produce a scattering of undershrubs, perennial grasses, perennial herbs, and some annuals. (Near Hollister, Idaho; June 4, 1928)

under the stimulation of high prices of wheat and abandoned at the slump in prices; in part, tracts irrigated for a time and abandoned when a shortage of water occurred.

The denuded tracts, now in the early stages of the reestablishment of the original vegetation, are covered with weeds, chiefly these five annuals: Tumbling mustard, flixweed [7] (*Sophia parviflora* (Lam.) Standl.[8]), green tansy mustard (*S. longipedicellata* (Fourn.) Howell [9]), Russian thistle, and downy bromegrass (*Bromus tectorum* L.).

The principal weeds that first occupy the denuded lands—tumbling mustard, flixweed, green tansy mustard, and Russian thistle—are of special economic significance on such areas because they serve as

[7] Also known as herb sophia.
[8] Synonyms: *Sophia sophia* (L.) Britton; *Sisymbrium sophia* L.
[9] Synonyms: *Sophia filipes* (A. Gray) Heller; *Sisymbrium incisum filipes* A. Gray.

favorable host plants for the beet leaf hopper. As opposed to these weeds, downy bromegrass, an introduced annual which appears somewhat later on the denuded lands, is not a host for the beet leaf hopper. The greater the area of the weed hosts in a region otherwise favorable for leaf-hopper development the greater will be the leaf-hopper population. Moreover, it has been found that the most serious damage to sugar beets, tomatoes, beans, squash, and certain other crops which may be grown in the region occurs when there are large leaf-hopper populations. The damage to these crops does not result from the leaf hopper itself but is due to the virus disease, called curly top, which the insect carries from diseased wild host plants or diseased beets to healthy beets. The cultivated crops are infested during the late spring or early summer movement of the leaf hoppers from their early-maturing food plants to those that continue green and succulent until late summer or fall.

Severin (*10*) reported that in California the insect breeds in enormous numbers on the winter annual alfileria (*Erodium cicutarium* (L.) L'Her.) and, when this plant dries up in spring, moves on to weeds and crops in the near-by cultivated areas.

Carter [10] first called attention to the significance of the large weed areas in southern Idaho from the standpoint of the leaf hopper and the curly-top disease. Haegele (*5, p. 6*) made an extensive leaf-hopper survey of Idaho and reported the occurrence of the insect on the principal weeds that have been mentioned. An observation of his, which is pertinent to the matter of the regular spring flight of the insect, is as follows: "The mustards mature early and are the principal hosts of the beet leaf hopper in the spring. They are gradually replaced in early summer by Russian thistle on which the insect was found the remainder of the season." The interrelationships of the insect and the weed hosts and also the sequence of the weed hosts through the growing season are discussed at some length by Carter (*3*).

The movement or flight of the leaf hopper from the one lot of food plants to another takes place annually in every region in which the insect occurs, and incident to this movement, as has been previously mentioned, any crops susceptible to curly top that are grown in the area over which the insects disperse are likely to be infested and damaged or destroyed.

EXTENT OF THE WEED AREAS

The Twin Falls region of southern Idaho was selected as a suitable place to begin an ecological study of the weeds mainly involved in the curly-top problem, because there in recent years the weed area has been greatly increased and also the disease problem has been greatly aggravated. A reconnaissance survey has been made of a portion of this area, including the Salmon River tract, but somewhat exceeding its boundaries, to show the acreage and distribution of the denuded and abandoned areas. (Fig. 2.)

A beginning on the map (fig. 2) was made in 1928. It was completed and some of the earlier portions were revised, so that the areas

[10] Walter Carter, formerly in charge of the Bureau of Entomology station at Twin Falls, Idaho, was largely responsible for the initiation of this ecological study of the weed areas in southern Idaho. Cooperative work is now being carried on with P. N. Annand, entomologist, Bureau of Entomology, in charge of the station.

are shown as they were in 1929. Locally the areas change from year to year, since weedy tracts, especially those adjoining or within the cultivated tracts, may again be plowed and outlying cultivated lands

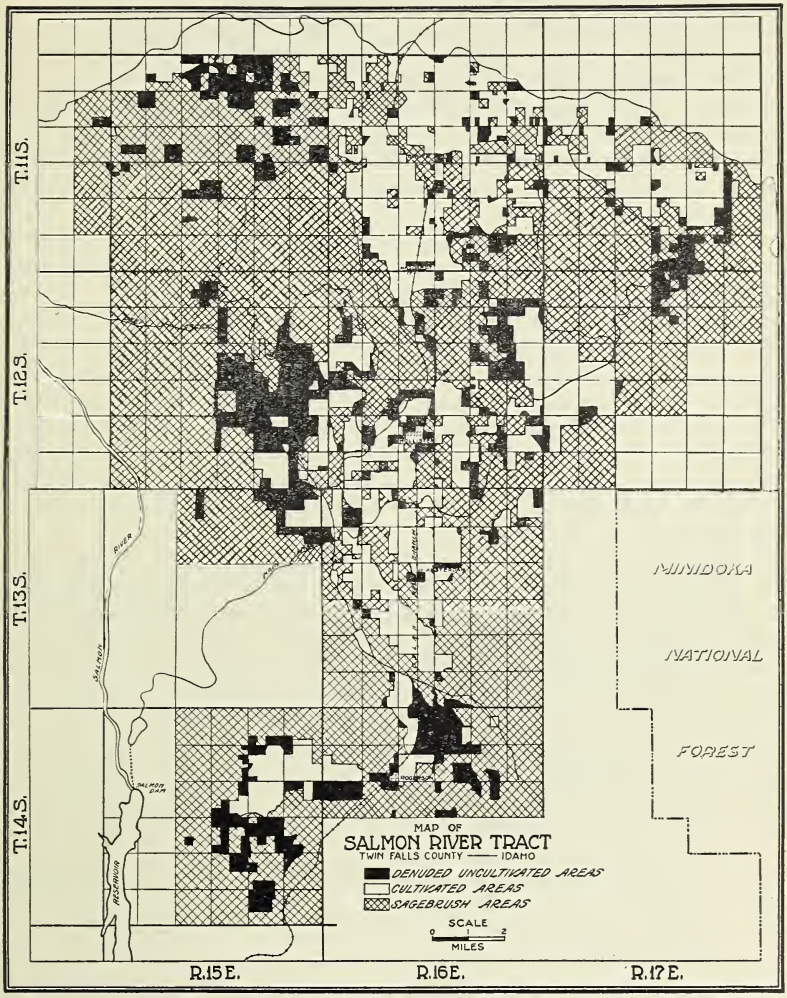

FIGURE 2.—Sketch map of a portion of the Snake River plains of southern Idaho, showing (in black) denuded uncultivated lands, formerly irrigated tracts now abandoned and for the most part covered with weeds, chiefly weed hosts of the beet leaf hopper. Land covered with native sagebrush is shown by crosshatching and cultivated land in white. North of this mapped portion lies a well-farmed agricultural area. The northern half of the mapped area in general is surrounded by agricultural areas; the southern half by immense stretches of sagebrush where completely denuded tracts are comparatively few and small. There are other areas in the Snake River plains similar to the one mapped. In the eastern and northeastern portions of the plains there are abandoned areas where attempts at farming without irrigation were made. In the middle northern portion of the plains there are immense burned sagebrush areas. All of them are for the most part covered with the weed hosts of the beet leaf hopper, though the oldest portions may have various admixtures of downy bromegrass, perennial grasses, or sagebrush, none of which are favorable hosts

may be abandoned. Taking the area as a whole, these changes can be considered slight. If, however, either the prices for farm products were greatly increased or the water supply temporarily be-

came much greater, the changes might be considerable. The immediate result would be an increased cultivation of present weed areas or even a further denudation of sagebrush, while abandonment would follow as soon as the stimulation was removed.

The denuded uncultivated tracts (shown in black in fig. 2) are for the most part outlying lands bordering the cultivated land (shown in white) and surrounded by the native sagebrush (shown by cross-hatching). The areas shown in black include all land that has been denuded of sagebrush and is not under cultivation. That is to say, besides the areas dominated by the four most important weeds previously mentioned, the parts designated as denuded uncultivated areas include some tracts, parts of which at least are well on the way toward a restoration of the original vegetation with perennial grasses, young sagebrush, or young rabbit brush (*Chrysothamnus* sp.), either dominant or equally as abundant as the weeds. The portions of the area shown in black do not include the partially denuded tracts where the original sagebrush is still standing but in which other plants of the original association have been killed, thus making place for weeds unless these partly denuded areas have been so definitely dominated by the weeds that they could be readily delimited. Of the total area considered in the reconnaissance survey, comprising approximately 180,000 acres, about 64,000 acres have been denuded, and of these 40,000 acres are in cultivation and 24,000 acres are weedy lands.

In mapping, an estimate was made of the type of growth on each tract, of the plants present, and of their relative abundance, that is, whether there was a mixture of two or more or whether the tract was plainly dominated by one species. From this as a basis the following estimates were made: Of the 24,000 acres of denuded land, 10 per cent is covered with Russian thistle, 7 per cent with tumbling mustard, 4½ per cent with flixweed, 17 per cent with a mixture of these three, 39 per cent with a mixture of the three and downy bromegrass, and 21 per cent with downy bromegrass or perennials, or a mixture of the two, in none of which the numbers of the first-mentioned three weeds were considered significant. Of the 17 per cent area covered with a mixture of the three weeds, tumbling mustard was one of the dominants on 82 per cent of it, Russian thistle on 75 per cent, and flixweed on 55 per cent.

The mapped area lies on the south side of the Snake River. On the north side of the river are immense areas of burned sagebrush which are now occupied by downy bromegrass and tumbling mustard. An inclusion of this area in the estimates would place the percentage of tumbling mustard above rather than below that of Russian thistle as given for the mapped area. Observations on other areas also indicate that on the Snake River plains as a whole the percentage of tumbling mustard would be greater than that of the Russian thistle, that of flixweed would be still lower, and that of downy bromegrass greater than the percentage given for the mapped area.

DISTRIBUTION OF WEEDS

The weeds of the entire area of the Snake River plains may be divided into two main groups: (1) Weeds of the irrigated lands; (2) weeds of dry or semiarid lands. (Fig. 3.)

The first group can again be divided into (*a*) those appearing on the fields with crops, chiefly annual mesophytes, and at least to some extent common to both humid and arid sections, and (*b*) those on

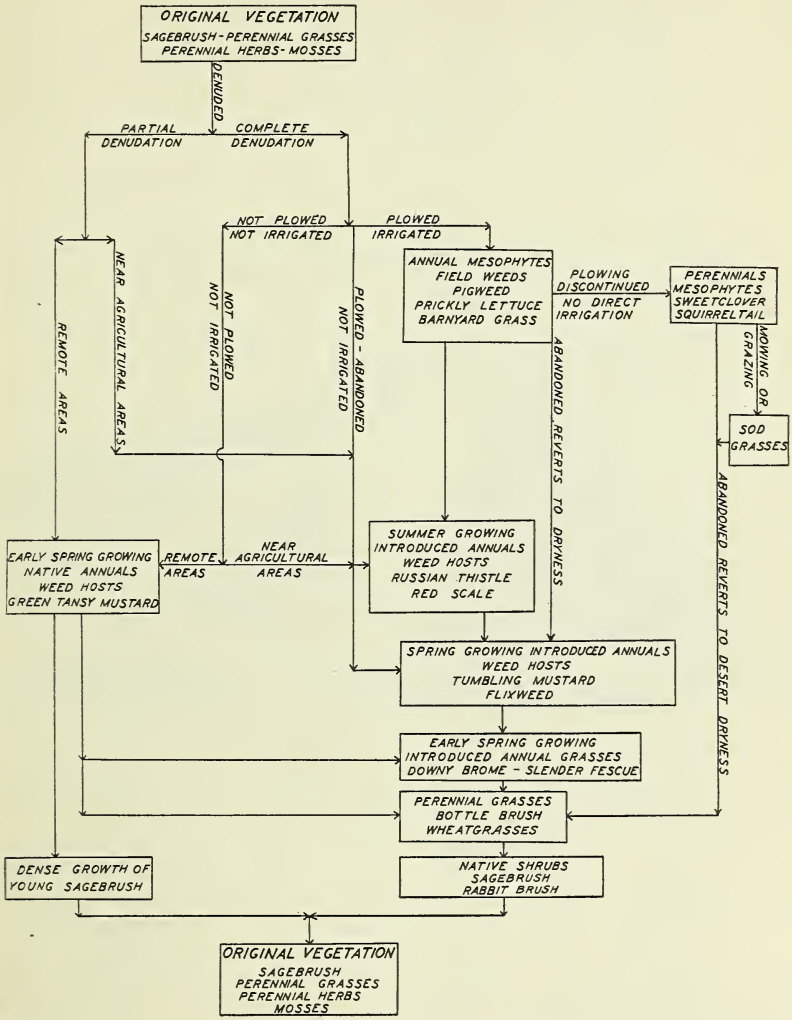

FIGURE 3.—Diagrammatic representation of the reestablishment of the original vegetation on denuded lands. The uppermost part of the figure relates to the early history of the tracts, such as the kind of denudation, whether partial or complete, and whether the tracts are plowed or not. The upper right represents the weed stages of the irrigated tracts before abandonment. In the lower right quarter are the stages, after the land reverts to desert dryness, from the first weeds (leafhopper hosts) to the shrubs. These are shown well separated here for the sake of clearness. Actually they overlap, most noticeably so in the case of perennial grasses. Excepting the latter, there are numerous large tracts that can be definitely assigned to the respective stages. The left of the chart concerns lands other than the plowed, such as burned or heavily grazed lands, which may be either completely or partly denuded. These may either pass quickly from a weed to the shrub stage, or one or other of the intermediate stages (on the right) may appear

lands that are within the irrigated section but are not directly irrigated and are not plowed, such as the strips of waste land along ditches, roadsides, and the borders of fields. Mention of a few of

these plants will denote the types. In the first subdivision (*a*) are pigweeds (*Amaranthus retroflexus* L. and *A. graecizans* L.), lamb's-quarters (*Chenopodium* spp.), prickly lettuce (*Lactuca scariola integrata* Gren. and Godr.), red scale [11] (*Atriplex rosea* L.), and barnyard grass (*Echinochloa crus-galli* (L.) Beauv.). Under this class would also come the noxious perennials that survive ordinary cultivation, such as white top (*Lepidium draba* L.), Canada thistle (*Cirsium arvense* (L.) Scop.), quack grass (*Agropyron repens* (L.) Beauv.), and others. While economically of great importance, their distribution is extremely localized, and they would therefore not be listed among the principal weeds occurring on the average irrigated field. The weeds of type *b* are chiefly perennials or biennials such as sweetclover (*Melilotus alba* Desv. and *M. officinalis* (L.) Lam.), wild barley (*Hordeum jubatum* L.), wheatgrasses (*Agropyron* spp.), dock (*Rumex crispus* L.), poverty weed (*Iva axillaris* Pursh), goldenrod (*Solidago* sp.), and bull thistle (*Cirsium lanceolatum* (L.) Hill), with some large annuals, such as sunflowers (*Helianthus annuus* L.). This latter type (*b*), when frequently mowed or grazed, forms a grass sod, often seen along the roadside.

The second group, the dry-land weeds, can be subdivided into (*a*) introduced annuals of the abandoned tracts, of ill-kept fallow lands, or of denuded lands adjacent to those, and (*b*) native annuals of the isolated denuded tracts remote from agricultural districts and surrounded by vast areas of sagebrush. The tumbling mustard, flixweed, and Russian thistle, previously listed as weed hosts, as well as downy bromegrass, which is not a host, belong in class *a* of this second group. Because of their significance in relation to the beet leaf hopper, a more detailed account of their distribution is given in the following paragraphs. Chief among the plants of class *b* are green tansy mustard, stickseed (*Lappula occidentalis* (S. Wats.) Greene), and other borages (*Amsinckia tesselata* A. Gray, *Cryptanthe* sp., and *Pectocarya penicillata* (H. and A.) A. DC.). These are also the principal weeds on tracts remote from agricultural areas where the sagebrush has been partly destroyed and the perennials killed out by trampling and heavy grazing.

Of the dry-land weeds, Russian thistle is the pioneer on bare lands. It is the first on the raw, limy, rocky subsoils such as the mounds from excavations and the bare strips along roads and railroads where the upper soil has been scraped off for the grades. It is a notorious weed on the ill-kept fallow lands of the nonirrigated districts as well as of the outlying insufficiently watered fields of irrigated sections. It forms conspicuous narrow strips, dark green in summer and reddish in the fall, which fringe the nude edges of railroad grades, roadways, and trails. (Fig. 4.) Of the five principal dry-land weeds, Russian thistle is the most closely confined to the agricultural areas. In traveling from the farming districts out into the surrounding large areas of sagebrush, Russian thistle is the first to be lost sight of. It is a less common weed than tumbling mustard on the immense burned sagebrush tracts and the older abandoned tracts. An explanation of the fact that Russian thistle dominates a greater acreage in the mapped tract than the tumbling mustard may be found in that the mapped area includes a greater percentage

[11] Also known as red orach.

of recently tilled and abandoned land than does any equal area of the Snake River plains, and also in the readiness with which Russian thistle covers such bare lands.

The flixweed is almost as closely confined to the agricultural areas as is the Russian thistle. Perhaps more often than the latter, it may be found far out in the sagebrush around old sheep-camp sites. It is especially abundant on abandoned stubble fields, in almost pure stands, or what is more common, associated with tumbling mustard or Russian thistle. (Fig. 5.) It is a common weed on abandoned land amongst the alfalfa tufts. (Fig. 6.) In this respect it is like downy bromegrass but contrasts with tumbling mustard and Russian thistle, neither of which are frequent in old alfalfa stands.

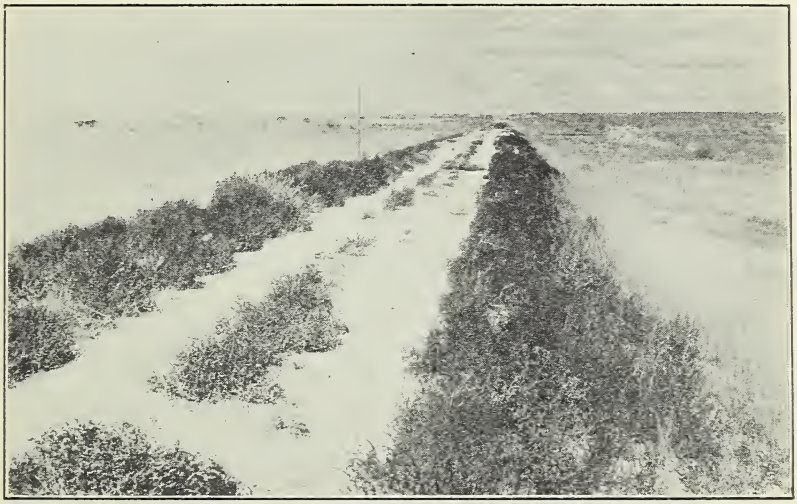

FIGURE 4.—A very common arrangement of the weeds along a little-used road. A dense dark growth of Russian thistle fringes the bare wheel tracks. Below the Russian thistle (the light area to the right) is a tall growth of flixweed. In a dense growth of Russian thistle, as above, very few seedlings of this plant appear the following season, and almost none survive if the parent plants remain in place. Flixweed seedlings may appear and survive to a limited extent, while downy bromegrass and other grasses may grow in considerable numbers and mature. (Near Hollister, Idaho; Oct. 14, 1930)

The tumbling mustard is distributed considerably farther out from the farming areas as compared with Russian thistle and flixweed. It stretches far out into the sagebrush along the burns, where it may form fairly pure stands, or it may be variously mixed with downy bromegrass. As to the area dominated by this plant, it exceeds all the others but downy bromegrass. Of the introduced annuals it is by far the most common on recently burned sagebrush lands. (Fig. 7, foreground.) As mentioned above, it is also one of the three principal weeds on abandoned stubble fields. On the sandy, hummocky lands it forms a fine large growth, though not a dense cover. It is not abundant on the heavier greasewood soils of high salt content.

Downy bromegrass exceeds any one of the other plants under consideration in both the extent of distribution and the area dominated by it. It extends in all directions to the hills surrounding the plains and is to be found practically wherever sagebrush has been

destroyed. The bench lands and the edges of the plains next to the foothills show immense uniform areas of downy bromegrass on burned-over sagebrush lands. Large portions of these areas are quite free from the introduced weed hosts of the leaf hopper. (Fig. 8.) The densest growth occurs on the hills next to the junipers, where it is sometimes tall enough to cut for hay. The plants are smaller toward the center of the plains, and the stand less dense. On soils with a high salt content downy bromegrass is almost lacking. In the hummocky, wind-blown, sandy soil the plants are tall and well developed, but the stand is sparse.

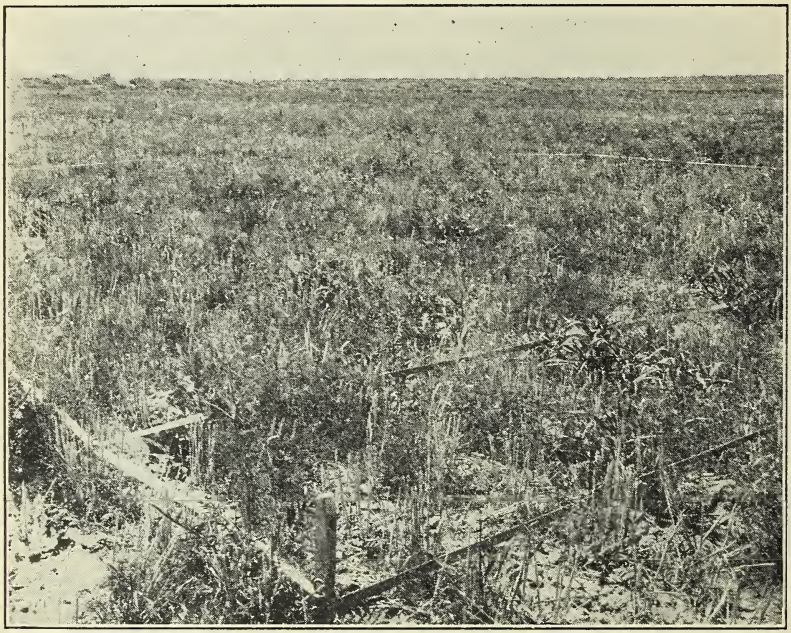

FIGURE 5.—A stubble field which, the season following the shutting off of irrigation water, produced a mixture of the plants of irrigated fields (prickly lettuce and volunteer wheat) and the weeds of dry lands (Russian thistle, flixweed, and tumbling mustard). Most of the prickly lettuce and almost all the wheat dried up before flowering. The dark, sharply defined plants are prickly lettuce and wheat. The dark, smoky, indefinitely outlined plants are Russian thistle. Tumbling mustard and flixweed are present but inconspicuous. (Near Hollister, Idaho; June 14, 1928)

Green tansy mustard, a widely distributed native annual, belongs to subdivision *b* of the dry-land weeds. Its distribution as well as its origin contrasts with the introduced weeds discussed above. While it may be found to a slight extent on the abandoned tracts with the introduced weeds, its chief distribution is away from rather than near to agricultural areas. It is scattered throughout the sagebrush, its abundance being dependent on the condition of the sagebrush and the perennials associated with it. When heavily grazed and trampled where the sagebrush is poor and the perennials mostly killed out, there is a considerable covering of green tansy mustard in the soil spaces among the bushes. It is ever present around animal burrows, ant hills, and other local soil disturbances in the large areas of sagebrush.

A peppergrass (*Lepidium perfoliatum* L.) is a weed frequently seen in the Snake River plains. At present it is largely confined to the towns, where it is very abundant on dry vacant lots. It is not as yet an important weed on the large denuded tracts.

BRIEF CONSIDERATION OF THREE OTHER REGIONS

ESCALANTE VALLEY OF UTAH

The Escalante Valley of Utah, a long, narrow valley, at one time the southernmost bay of the ancient Lake Bonneville, has an average elevation of about 5,000 feet and an average annual precipitation

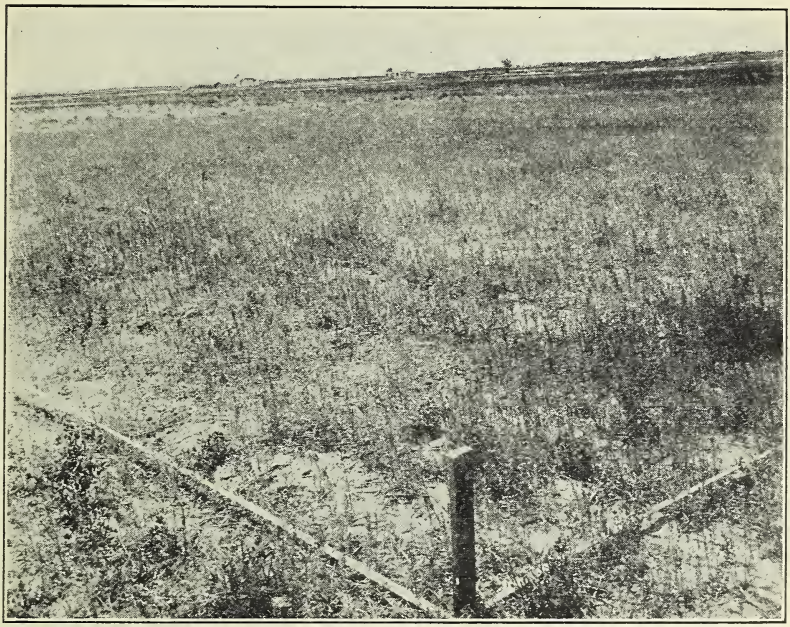

FIGURE 6.—A field that was abandoned at the same time as the stubble field shown in Figure 5. Here on a field which was insufficiently watered the year before and which bore a scant alfalfa crop, the stand of dry-land weeds is well developed at the time of abandonment. The plants here are almost entirely of one species, flixweed. The number of the plants is great, but the plants are slender and short, contrasting with the more luxuriant, well-developed, and much less numerous plants of the stubble field. (Near Hollister, Idaho; June 18, 1928)

of about 10 inches. The valley resembles the Snake River plains as to temperature and total precipitation, but differs as to the distribution of the precipitation in that less occurs in the winter months, a greater proportion in the summer months, and at Modena, in the southern end of the valley, a considerable portion occurs in July and August. As compared with the Snake River plains, the Escalante Valley has poorer drainage and the heavier alkali lands form a considerable portion. Here sagebrush, which in the Snake River plains was all but a universal covering, is less important; greasewood covers considerable areas; shad scale likewise, with the salt-grass and rabbit-brush types well represented. At the southern end of the valley there are grassland areas.

The total area of abandoned lands is not so large as that of the Snake River plains. The immense areas of tumbling mustard are lacking, and the plant is confined largely to the railroad grades and sandy areas. The weed common to the two areas is the Russian thistle, which in the Escalante Valley assumes a far greater importance. It is seen everywhere on denuded lands, whether sagebrush, shad scale, grass, or rabbit-brush lands, down to the flats of the valley. Russian thistle is the most common host for the leaf hopper in Utah, according to Knowlton (*8*), who considers Escalante Valley as one of the important breeding areas for the insect.

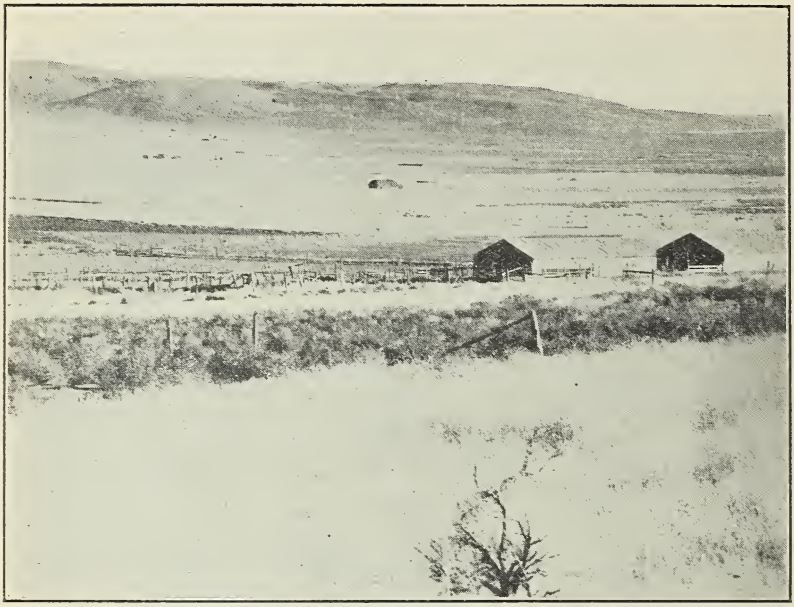

FIGURE 7.—A characteristic grouping of weed areas around a farmyard. In the foreground is a burned sagebrush area now covered with a dense stand of tumbling mustard. The dark area just beyond is a rank growth of red scale on the site of an old corral. The shaded area at the left of the sheds, in the fenced areas, is Russian thistle, while at the extreme left the dark wedge-shaped area is newly plowed land. The extremely light area in the middle background in front of the straw stack is downy bromegrass with dark strips of sagebrush appearing from the right. Beyond are alternations of stubble fields and downy bromegrass with smaller areas of weed hosts. (Near Hollister, Idaho; Oct. 22, 1930)

On the lower lands, denuded greasewood areas, there is found the other principal weed of the valley, a blistercress (*Cheirinia repanda* (L.) Link). In contrast with the tumbling mustard and the flixweed, it forms its best stands on the bottom lands excepting those with very high concentrations of alkali. It is perhaps second in importance to Russian thistle but covers a comparatively small acreage. Of the mustards it is the only one forming anything like a fair covering over an area of any size. The tansy mustard (*Sophia pinnata* (Walt.) Howell) is to be found usually as widely scattered individual plants, and peppergrass (*Lepidium* sp.) is of secondary importance. Both of these plants are usually associated with the blistercress on the denuded greasewood lands. With these is also

associated the more conspicuous seepweed (*Dondia depressa* (Pursh) Britton).

MOJAVE DESERT

The Mojave Desert, a desert plateau of California with an elevation of 2,000 to 3,000 feet, has a very low annual precipitation, less than 5 inches, most of which occurs in the winter months. The mean annual temperature, about 64° F., is high as compared with the mean of approximately 48° of the Snake River plains and the Escalante Valley. There are large areas of sandy or gravelly soils as well as the heavier alkali soils. The sagebrush or northern desert shrub type is present but forms an inconsiderable part of the vegetation. The prevailing type is the creosote bush (*Covillea triden-*

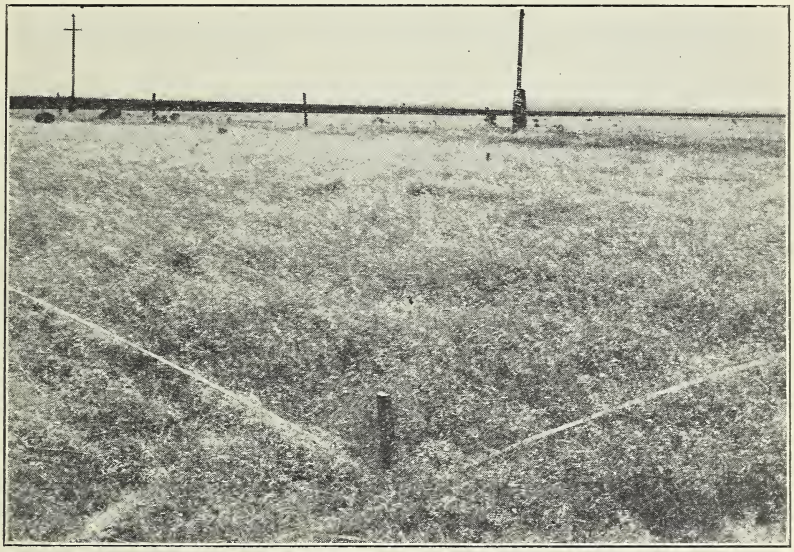

FIGURE 8.—A dense growth of tall downy bromegrass, selected to represent a pure stand. The present year's growth is entangled with the remnants of the growth of the preceding year. There are some old stalks of tumbling mustard of the previous year's growth, but there are no living plants. A few tufts of perennial grasses were recorded. Such a stand is very effective in excluding weed hosts of the leaf hopper. Tracts of this kind are numerous and large, but they are easily destroyed by burning and subsequent heavy grazing. Upon destruction, the weed hosts again appear in an irregular first stage. (Near Hollister, Idaho; June 18, 1928)

tata (DC.) Vail), desert sage[12] (*Atriplex polycarpa* (Torr.) S. Wats.), or southwestern desert shrub type.

There are considerable tracts of abandoned farm lands in several localities, but the percentage of the whole area is small. Russian thistle covers the more recently abandoned lands or neglected fallow lands. On the dry heavier soils it is closely confined to plowed lands, those between Rosamond and Palmdale and those southwest of Barstow on the flood plains of the Mojave River, toward Oro Grande. It occurs in localized areas on the sandy soils and in the dune areas, and here it will probably spread. The prevailing weed type of the desert and the one that covers lands denuded of brush

[12] Also known as desert saltbush.

but where there has been no plowing is in general that found in the southwestern desert shrub type of vegetation. A more detailed list of these annuals is given in the study of this type by Shantz and Piemeisel (*11*). The principal plants are alfileria (*Erodium cicutarium* (L.) L'Hér.) and red bromegrass (*Bromus rubens* L.), with which are usually associated species of Amsinckia, Plantago, Thelypodium, Sophia, and Lepidium. An annual Eriogonum, reddish when dry, is a conspicuous plant on many denuded areas. In most years the annual flora is sparse, in the driest almost lacking. The heavier alkali soils of the flats are practically bare of annuals. When denuded they remain bare for a longer time when the seepweed (Dondia) forms a scattered growth.

The occurrence of the beet leaf hopper in abundance in the Mojave Desert has been reported by several workers.

SAN JOAQUIN VALLEY OF CALIFORNIA (SOUTHERN PORTION)

The San Joaquin Valley of California slopes gradually northward from an elevation of somewhat over 400 feet in the southern part. Its low annual rainfall, about 5½ inches in the southern part, consists chiefly of winter rains, the summer being practically rainless. The mean annual temperatures, approximately 65° F., is slightly higher than that of the Mojave Desert. There are wide bottom lands which are now irrigated for crops, but there is a considerable area of abandoned lands with a high water table and high salt content, now covered with salt grass and seepweed, or annual saltbushes (*Atriplex* spp.). East of the bottom lands the slopes which rise toward the foothills and which were once covered with bunch grasses are now dry farmed. A short account of the seasonal development of the annual type that appears on the alluvial farms on the north side of the Tehachapi Mountains is given by Bauer (*2*). The west side, dry and quite barren plains, was once covered with the desert sage type of vegetation but is now mostly denuded. There is a covering of annuals, after the winter rains, which dry up in the spring. In the dry years the growth is sparse, the plants small. The type of weed growth is similar to the Mojave, alfileria and red bromegrass with associated species—peppergrass, lupines, borages, and several annual composites. The stand varies from a quite complete to a very patchy cover. Grazing and erosion combine to retard the growth and the return of the original plant covering. Unpalatable species are favored, such as *Isocoma veneta acradenia* (Greene) H. M. Hall, which is already abundant on some of these lands, and the pricklypear (*Opuntia* sp.), which has formed dense stands on localized areas.

In the southern part of the San Joaquin Valley the large areas of Russian thistle so common in the Snake River plains and the Escalante Valley are lacking. It is scarcely to be found on the desert-dry compact soils formerly occupied by the desert sage. A scattered growth may occur where the soil has been recently disturbed, as on plowed lands or the loose soil of railroad and road grades. Russian thistle occurs to a somewhat greater extent on the lands above the desert sage plains, that is, on the lands formerly occupied by bunch grass. Here it may be found in considerable areas on alluvial fans, sparsely along roadsides, and to some extent at the

edges of dry farms. It is abundant on some of the more recently abandoned lands of the irrigated districts. The weed types of the greatest extent in the southern San Joaquin Valley are, however, alfileria, peppergrass, and red bromegrass of the dry lands and the annual saltbushes and seepweed type of the wetter lowlands.

The great abundance of weed hosts in this valley furnishes food for large populations of the beet leaf hopper every year and enormous numbers in some seasons.

COMPARISON OF THE FOUR AREAS

The following similarities and dissimilarities of the general types of weed growth of the four areas may be pointed out.

The early spring weed growth is well developed in the Snake River plains and also, in years of good rainfall, in the Mojave Desert and the San Joaquin Valley. While the Snake River plains on the one hand and the San Joaquin Valley and Mojave Desert on the other are very dissimilar as to mean temperatures and total precipitation, they are alike in that the distribution of the precipitation is favorable to the storage of an ample supply of moisture (snow and early spring rains in the first named, and fall and winter rains in the other two), followed by a period of moderate temperature in which the early spring-growing annuals may be developed and matured before the hot, dry summer months.

The early spring weed population of the Mojave Desert and the San Joaquin Valley is a scantier, shorter growth, uncertain in its appearance, and in years of very low rainfall may be almost lacking. It is represented by alfileria, peppergrass, and red bromegrass, while that of the Snake River plains is represented by tumbling mustard, flixweed, green tansy mustard, stickseed, and downy bromegrass.

The summer-growing weed type exemplified by the Russian thistle, which makes its greatest growth in the hot, dry summer months, is at its best development in the Escalante Valley, where there is a tendency toward a summer rainfall. The Russian-thistle type is also of considerable importance in the Snake River plains, where there is some summer rainfall. It is of slight importance on the denuded desert-dry lands of the southern San Joaquin Valley and in the Mojave Desert, where the summers are practically rainless, and where, moreover, it is confined to plowed lands or to the loose soils of road and railroad grades. In the Imperial Valley of California, with a low rainfall and a long, hot, rainless summer, Russian thistle is practically lacking on any type of land and is never seen on the desert-dry soils.

In both the Imperial and the San Joaquin Valleys the summer-growing weed type is better exemplified by the annual saltbushes of which there is a considerable acreage that lies almost wholly within the irrigated sections.

The type of weed growth occurring with the irrigated crops of these four areas, while dissimilar as to species, is alike in general nature—summer-growing annuals, some of which at least are to be found in considerable numbers alike in humid and arid agricultural regions.

It may be of interest here to point out in a general way the region in which Russian thistle occurs as one of the dominant weeds on de-

nuded dry lands. It extends westward from the Snake River plains to eastern Oregon and Washington, across the Canadian border, including the southeastern corner of Alberta, almost to Calgary and the southwestern corner of Saskatchewan, down the Great Plains to Texas, then west to California, touching the Mojave Desert and the San Joaquin Valley. Tumbling mustard is coequal with Russian thistle in that part of the above-mentioned region north of the Snake River plains, but it is not of importance in the southern portion.[13] The area of most extensive development of the Russian thistle is south and east of the Snake River plains, while that of tumbling mustard is to the north and east.

REESTABLISHMENT OF ORIGINAL VEGETATION IN THE SNAKE RIVER PLAINS

GENERAL CONSIDERATIONS

A general view of the various stages is shown in Figure 3. As stated above, the original vegetation of almost the entire Snake River plains was sagebrush (fig. 1), with its associated perennial herbs and perennial grasses and a matting of mosses in the shade of the shrubs. The type as it appears in Tooele Valley, Utah, has been described in some detail by Kearney et al. (9).

With clearing, with the destruction of the original vegetation, and with irrigation, there appeared a new set of plants—introduced weeds—which covered the ground not actually covered by the crop plants. These are described on page 8 under subdivision *a* of weeds of irrigated lands. They are adapted to the moist irrigated lands, and in fact some of them are also to be found in the fields of humid sections. But on abandonment and as the soil reverts to desert dryness, these weeds disappear for the most part in the first season. This is most noticeable in a field where there is a sudden change from a plentiful irrigation to no irrigation the following season and a correspondingly great change in the soil moisture. More often a field has been insufficiently watered for one or more seasons before abandonment, so that there is a poor crop stand, and the dry-land weeds, which are infrequent in well-watered fields, have at abandonment already become very numerous. (Fig. 6.) At abandonment the lands may be bare, in stubble, or in alfalfa. The first year after abandonment the bare lands are most likely to be covered with Russian thistle. The stubble fields one year after abandonment are commonly occupied by one or more of these three—tumbling mustard, flixweed, or Russian thistle, and the alfalfa fields with a short stand of flixweed or downy bromegrass amongst the alfalfa tufts. The following seasons there is a greatly increasing density of the particular dominant weed with a tendency for the individuals to become depauperate.

At about this time the weed hosts of the leaf hopper are most abundant on the abandoned tracts. It is at this time too that a rapid extension of downy bromegrass is favored. It appears first as widely scattered single plants which may date from the time of

[13] The statement takes into consideration the fact that both tumbling mustard and Russian thistle are found outside of the regions given, though under local and special conditions. Thus tumbling mustard occurs in the Mojave Desert on some abandoned lands within the juniper area.

abandonment. From the single plants patches may develop which increase in area with a corresponding decrease of the area and number of the weed hosts, until finally downy bromegrass is dominant. (Fig. 9, also fig. 8.)

Perennial grasses may appear shortly after abandonment as widely scattered individuals. The one commonly appearing early is the bottle brush (*Sitanion hystrix* (Nutt.) J. G. Smith). Later there are established one or more of the following: Montana or Rocky Mountain wheatgrass (*Agropyron riparium* Scribn. and Smith), Sandberg's bluegrass (*Poa sandbergii* Vasey), and Thurber's needle grass (*Stipa thurberiana* Piper). Other perennial grasses

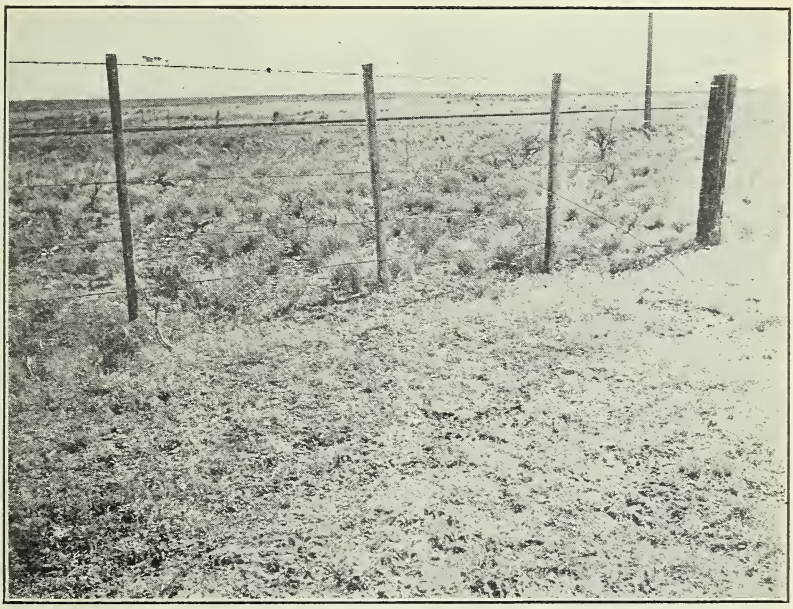

FIGURE 9.—The areas on the two sides of the fence represent (in the foreground) a stand of short but fairly dense downy bromegrass on an old abandoned field and (beyond the fence) a stand of perennial grasses (species of Sitanion, Poa, Stipa, Agropyron, and Oryzopsis) on burned sagebrush land. The downy bromegrass (foreground) is subject to some grazing; the perennial grasses are not. Both are frequently burned. The weed hosts of the leaf hopper are not abundant in either area. However, continued trampling and grazing may rapidly increase those in the downy bromegrass of the foreground, while in the protected area beyond the fence the weed hosts will continue to decrease in number. (Near Hollister, Idaho; July 16, 1929)

appear under local and special conditions, namely, needle and thread grass (*Stipa comata* Trin. and Rupr.), Indian mountain rice (*Oryzopsis hymenoides* (Roem. and Schult.) Ricker) on sandy soils, and giant ryegrass (*Elymus condensatus* Presl.) on subirrigated soils or in drainage sumps. The increase in numbers of the perennial grasses is slow compared with the increase of the downy bromegrass and it is not until the land has been abandoned for a good many years that their abundance is marked. Eventually they may become as dominant as does downy bromegrass in the earlier stage, and the exclusion of the noxious weed hosts may become as pronounced, but not so uniformly over large tracts under the present system of grazing.

On the older abandoned areas where the perennial grasses are well established, the shrubs have usually become evident as scattered plants. The numbers of the shrubs are greater on the west or prevailing wind side, or, where the tract is not surrounded by sagebrush, on that side which is adjacent to the sagebrush. Of the two shrubs rabbit brush and sagebrush, the former spreads more rapidly. The two are commonly seen together on the older abandoned tracts. However, rabbit brush does not cover large-sized areas here as it does in the Escalante Valley, Utah.

There are abandoned tracts of long standing where the sagebrush has covered the ground to such an extent that the old borders of the

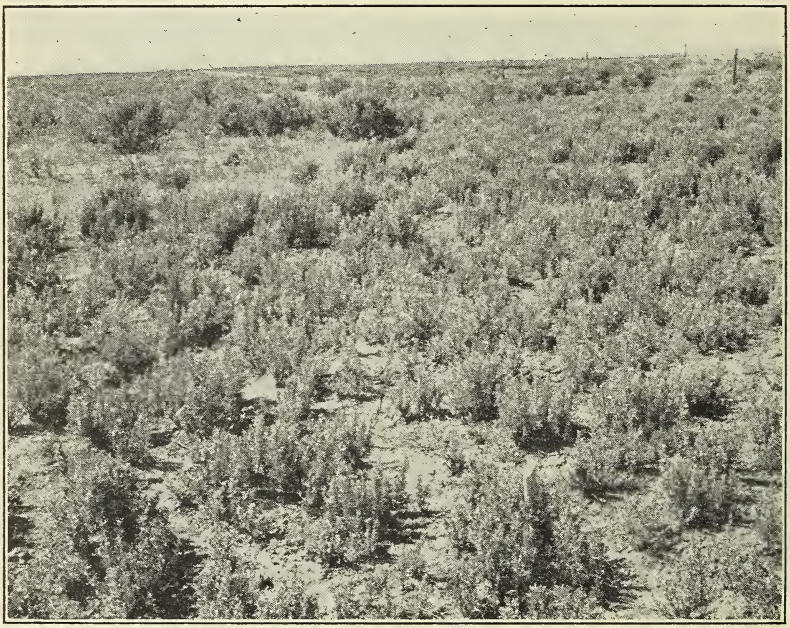

FIGURE 10.—Sagebrush on cleared land. On such lands, not plowed, a dense stand of sagebrush may develop rapidly after a weed stage of very short duration. The downy bromegrass and the perennial grass stages may be poorly or not at all represented. Such a cover is effective in its exclusion of the weed hosts of the sugar-beet leaf hopper. Areas of this kind are quite frequent but usually cover small tracts. The sagebrush plants in the foreground are 5 to 7 inches high. The upper corner is occupied by downy bromegrass (light area) and some large survivors of the former sagebrush cover. (Near Hollister, Idaho; June 19, 1928)

field can be recognized only after close scrutiny. Closer examination shows that the moss mats found in the shelter of the sagebrush plants in the original stand are lacking in the newer growth, and so too, though to a less extent, are the perennial herbs. As for the sagebrush plants, they are remarkably uniform and well developed, in fact to such a degree that there is a noticeable lack of old dead branches and of the dead plants so characteristic of an old sagebrush area.

It may happen that after a burn or after "railing off" the brush, the sagebrush will return quickly with no other but an annual weed stage of short duration intervening. The growth of sagebrush as

shown in Figure 10, is dense and of a remarkably uniform and pure stand. This does not happen on the abandoned lands where successive plowing has destroyed all of the original plant growth and the seed stored in the ground as well, nor does this apply to extensive tracts in the Snake River plains.

RETARDING FACTORS

Taking into account all the abandoned lands in the Snake River plains, it can be said that, in general, the recently abandoned lands are covered with weeds the bulk of which are hosts of the leaf hopper, while those abandoned for a longer time are covered with mixtures of weed hosts and nonhosts of which downy bromegrass, perennial grasses, and shrubs form a large part. Among the older abandoned tracts there are those which are definitely covered by downy bromegrass or by sagebrush. These tracts are striking in that though one of these covers may contain admixtures of the other or of perennial grasses, the tracts as a whole are remarkably free of the weed hosts.

The present system of grazing prevents such a development over the entire region. Many of the large older abandoned tracts when viewed early in the spring give a definite impression of being covered entirely by grasses. The grasses are then fairly well developed, while the mustards are still in the rosette stage or at least inconspicuous. After heavy grazing the grasses are eaten to the ground and in turn become inconspicuous, while the mustards develop rapidly and in a short time seem to dominate the area. Good-sized tracts of perennial grasses invite concentrated grazing and with it the very harmful trampling. If this is continued to the point where portions of the stand are destroyed, the noxious weed hosts again form colonies. Their numbers, however, over an older abandoned area as a whole will never be so great as on the recently abandoned tract, with the exception already noted, namely, the smaller fenced tracts where the stock is confined and the destruction of the plant cover may be complete so that the process of reestablishment begins again.

Grazing accompanied by burning is especially destructive of a good stand of downy bromegrass and is a hindrance to a reduction of the weed hosts. Downy bromegrass is readily eaten in the early spring and up to the time that ripening makes the awns objectionable. If all the old material is burned off, each plant and blade is thoroughly exposed. Grazing then is very harmful, and if continued into late spring [14] the ground may be seen strewn with the roots and the immature heads of the downy bromegrass. There is then an opportunity for the undesirable weed hosts to reenter, and usually a dwarfed form of Russian thistle predominates.

Fires, in extremely dry years, beginning where there has been a sufficient accumulation of wind-blown plant débris and fanned by a high wind, may burn large areas of sagebrush and greatly increase the denuded area. As a retarding factor, fire is most effective combined with grazing on stands of downy bromegrass as mentioned above. Aside from this, the burning of a cover of downy bromegrass

[14] Late spring grazing on the Snake River plains is dependent on the arrival of the dry weather. When the water holes dry up the sheep are run up into the higher mountain valleys to stay for the summer months.

of long standing has a retarding effect in that it destroys seedlings of the longer-lived perennials, notably sagebrush and rabbit brush.

Other factors that may cause disturbances of the various stages are the burrowing animals and ants. The areas damaged are small but numerous, and the total is large enough to be mentioned in this connection.

Badgers, jack rabbits, ground squirrels, and gophers do considerable damage to the existing plants and also by burrowing bring up loose soil which offers a suitable foothold for the objectionable weeds. Ants clear areas, from 3 to 18 feet across, of every vestige of plant material. The bare areas are wind swept and washed by the rains so that the soil surface is hard and compact. The weeds grow readily only at the outer fringe of the area and on the small mounds in the center after the ants have abandoned the mounds.

DURATION OF STAGES

The question of the duration of the weed growth on the denuded lands is of considerable interest because of its close connection with leaf-hopper population. How long can the weed growth on denuded lands be expected to persist? How long will it be before the original vegetation reestablishes itself? It is obvious that no definite answers to these questions can be given until observations and experimental data over a considerable period are available, and that even then the answers must be qualified by a statement of the conditions under which the reestablishment of the vegetation takes place. However, some idea of the time required may be formed from tentative estimates based on observations in the Snake River plains.

There are, for instance, tracts which 15 years after clearing have been covered with a dense growth of young sagebrush. (Fig. 10.) The uniformity of these stands suggests there were no severe disturbances or setbacks and that this probably represents the shortest time; that is, it is a development under optimum conditions. It should be noted that here the weed hosts of the beet leaf hopper are lacking and that they had been lacking for perhaps 5 years previously.

Other tracts subjected to the annual grazing and trampling show, 15 years after abandonment, a fringe of scattered young sagebrush near the edges, while the rest of the tracts are covered with perennial grasses and weed hosts mixed in varying proportions, the latter covering one-half or more of the area. Here the rate is undoubtedly slower. At a rate proportionate to the development reached at the end of the first 15 years, it would take at least again as long, or about 30 years, to cover the ground somewhere nearly as effectively as in the case noted above where no retardation in the development of the sagebrush cover occurred.

In 10 years' abandonment, downy bromegrass may effectively cover a tract so as practically to exclude the weed hosts. It very often covers the spaces among the tufts in a thin alfalfa stand at the time of abandonment. On stubble fields where there is not too much grazing and where there is seed available from adjacent ditches and roadsides it may take over 5 and probably 10 years to cover the ground well. Where grazing is too heavy the downy bromegrass stand may be destroyed and there is, as discussed in the preceding paragraph, a long, slow development of perennial grasses and shrubs

with an admixture of a considerable number of the leaf hopper's weed hosts.

Observations on tracts abandoned 50 years ago are few, and the time is more doubtful. Some tracts considered to be of this age are covered with a stand of sagebrush in which the individual shrubs are scarcely distinguishable in size from those of the surrounding original growth, but the associated plants, especially the mosses, are lacking. It is the nearest approach to a complete return of the original vegetation. The uniformity of the new growth here suggests a development under favorable conditions without severe setbacks. If 20 to 30 years are allowed for a subsequent thinning of the sagebrush stand and for the entering of the perennial grasses and herbs and the mosses, the total would be 70 to 80 years, and under less favorable conditions probably 100 years and over for a return to the complete original cover.

The most effective cover produced in a short time is the one first noted, that of the dense stand of sagebrush. It is effective in the exclusion of the weed hosts and is least likely to be destroyed. Unfortunately it is limited in its extent and applies to a comparatively small portion of the denuded lands. Downy bromegrass, which may be even more rapid in covering the ground, is, however, much more likely to be destroyed.

FAVORABLE FACTORS

In view of the facts that the principal constituents of the weedy stands covering the denuded lands are favorable hosts which feed and favor the breeding of large numbers of the beet leaf hoppers, that the original vegetation contains comparatively few of these weed hosts, and that the grasses are not favorable hosts, any method that might hasten the reestablishment of the original vegetation or might aid in extending the grasses would be desirable as a method of reducing the numbers of the weed hosts and consequently the leaf-hopper population.

It has been pointed out elsewhere that unrestricted grazing is the greatest single factor in retarding either the reestablishment of the original vegetation or an extension of the grasses. This is emphasized here only because of its connection with the reduction of the numbers of the objectionable weed hosts, for it is well known and has been repeatedly stated by men concerned with range management. The statements regarding range improvement and controlled grazing, based both on observations over widely separated areas and more recently on experimental data on definite tracts, have been summarized by Clements (*4*) in a chapter on range improvement.

Studies on the improvement of the sagebrush range have been made recently by Hanson (*6*, *7*) in Colorado. Good stands of the native grasses were obtained on land denuded of sagebrush where light grazing was practiced for the first two seasons, after which the stands were heavily grazed for several years before sagebrush reappeared. To obtain the stands, grazing was restricted for two seasons. On the Snake River plains, which are at a lower altitude and presumably somewhat more arid, it is likely that the length of time would need to be longer. Palatable grasses can not be counted on to cover large tracts effectively without controlled grazing. Under present conditions there are no large tracts where perennial grasses by themselves cover the ground well enough to exclude the weeds. The nearest approach to this are the stands of the annual

downy bromegrass, which, however, lack permanence, as has been pointed out. Under present grazing practices the most effective cover both as to the rapidity of covering the ground and holding the ground against the undesirable weed hosts is sagebrush. This applies to plantings as well as to naturally established stands. These statements are made from the viewpoint of a reduction of the beet leaf hopper host plants under conditions as they are. However, the most economical use of the land involves a consideration of the forage value of the plant cover. While downy bromegrass and sagebrush have some forage value, it is very low as compared with the native perennial grasses, such as Montana wheatgrass, Sandberg's bluegrass, and Indian mountain rice. These grasses are not host plants of the beet leaf hopper. If grazing were regulated it might be possible to maintain a cover of grasses of high forage value and at the same time remove the constant, if indirect, menace of the weedy lands to sugar beets and other crops.

SUMMARY

Approximately 13 per cent of a portion of the Snake River plains of southern Idaho are denuded lands now covered with weedy stands, the principal constituents of which are favorable hosts feeding and favoring the breeding of enormous numbers of the beet leaf hopper. The original cover and also grass covers are not favorable for leafhopper development.

The distribution of the principal weed hosts of the Snake River plains is discussed and their relative abundance compared with three other regions of the Southwest.

The reestablishment of the original vegetation on such denuded tracts is traced from the time of abandonment, for agricultural purposes, of the lands. The plant cover in the intervening stages is successively the weeds of irrigated fields, annual weeds of semiarid lands, annual and perennial grasses, and finally shrubs.

The greatest single factor in retarding the reestablishment of the original vegetation is unrestricted grazing. Under the present system the reestablishment has progressed so that recently abandoned lands are distinguishable from the older abandoned lands, but the progress is too often slow and very irregular.

From the standpoint of the reduction in numbers of the weed hosts of the leaf hopper, downy bromegrass is the most rapid and most effective cover over large tracts. The stands, however, are very likely to be destroyed before being replaced by the longer-lived plants, and the destruction of the stand of downy bromegrass results in a return to an irregular first or weed stage. Sagebrush may, under certain limited conditions, be as rapid in covering the ground, and the cover be relatively permanent, but this occurs on rather small tracts.

With unrestricted grazing it is doubtful if stands of palatable perennial grasses can effectively cover and hold the ground to keep out the leaf hopper's weed hosts. Plantings are also to be considered ineffective unless there is some control over grazing. Under conditions as they are, sagebrush is considered the most effective and in the long run the most rapid cover, although the most economical use of the land would call for a perennial grass cover because of its comparatively high forage value.

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